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Seismic Features of Vibration Induced by Mining Machines and Feasibility to be Seismic Sources

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Abstract

The primary problem to carry out Seismic While Mining is whether the seismic signals, induced by vibration of mining machines, can be useful seismic sources. Firstly, this paper describes the seismic signals near filed induced by the shearer, boring machine and pneumatic drill respectively, and the signal features in time domain, frequency domain, autocorrelation functions. Secondly, shows the features of far field seismic signal emitted by the shearer, and the seismic interferometry of the record also is done. The result shows that the signal from the shearer is stronger in 1-400Hz, and contained pulses and periodic compositions, in line with the characteristics of the shearer mining; far field signal of the shearer is mixed with microseisms; the single-shot record can gain from the far field shearer signal via deconvolution and correlation, and the seismic features of the shearer and microseisms are similar; seismic signals emitted from the boring machine and pneumatic drill also have broad band features. The experiential studies suggest that the vibration signals induced by the mining machines can be seismic sources.

Keywords: seismic while mining; coal mining; signal features; seismic source; seismic interferometry

1. Introduction

Prediction ahead of mining is always an important issue in coal mining safety, and methods such as direct current method, electromagnetic wave method, and elastic wave method have been used [1-6].

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Among these methods, elastic wave method has advantages of higher resolution, farther survey distance, but requires blasting or hammering or other methods to generate artificial seismic waves, and it is difficult and costly to implement. This paper takes the idea of Seismic While Drilling (SWD), proposed 'Seismic While Mining (SWM)', and got some preliminary results. SWM is a new prediction method finding collapse column, gob, or other geological hazard ahead of working face, using elastic wave emitted from mining machines as seismic sources, recorded in tunnel or at the surface (Fig.1).

An accelerometer was installed near the shearer and the source signal it recorded as pilot in data processing. Correlation of pilot and records in geophones line in tunnel or at the surface can retrieve Green's functions. Green's function contains the direct wave and reflective wave from anomalies and so on. The advantage is not disturbed coal mining operations, continuous real-time detection, and high resolution.

The primary problem to carry out Seismic While Mining is whether the shearer can be a useful seismic source. Taylor et al [8] studied the features of shear as a source, showed that frequencies of at least 2000 Hz are generated as both shear and compression energy, and geophone records had spurious frequencies in the 900-1200Hz range, which were suppressed with predictive deconvolution. Luo Xun et al [9,10] showed broad band frequency spectrum of signal from the shearer, as measured at different geophones, the shearer-geophone distances are from 140m to 317m, and believed that the shearer is a good seismic source. In this paper, near field three-component vibration signals of coal mining machines are acquired, which contained a variety of compositions, some are similar noise and some are periodicity; far field seismic signals emitted by the shearer were recorded at the surface, time-varying characteristics, spectrum feature are studied, and try to imagine with correlation; seismic signal features of the boring machine and pneumatic drill also be shown.

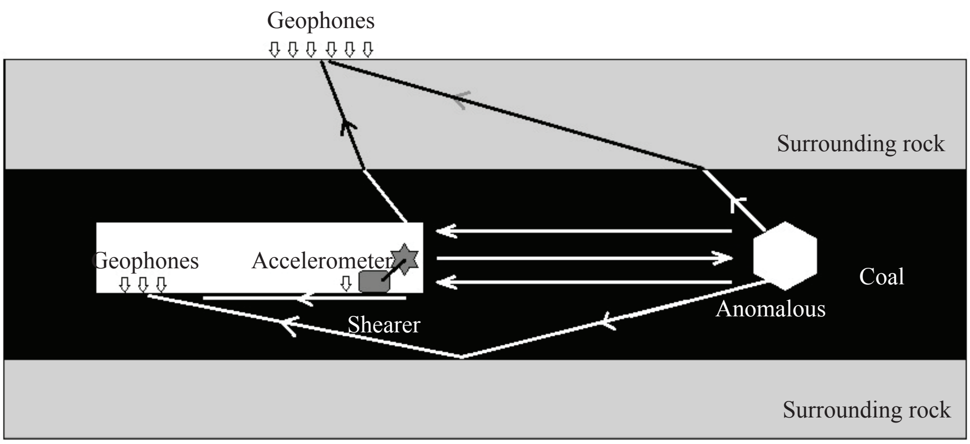

Fig. 1. Principle of Seismic While Mining

2. Field test

Field test in two parts: underground coal mining near-field source signal acquisition and signal far-field signal acquisition at the surface.

Underground test has special requirements to equipments: Firstly, the instruments must be explosion-proof requirements; secondly, near-field signals rich in high frequency components and require recording instrument to record broadband signal; in addition, the equipment should be small and easy to install. Test with the underground sensors developed by Xi'an Research Institute of China Coal Technology & Engineering Group Corp, sampling frequency of 4000Hz, recording time is 1s, 6 traces. Using magnetic block, detector can be closely adsorbed on the coal mining machinery or coal wall. The seismic data are recorded respectively at baseboard of hydraulic support in the vicinity of the shearer, at the corner of working face and air return way, in air return way about 100m away from the shearer multiple data are recorded. Signal of the boring machine is recorded near the driving place, and signal of the pneumatic drill is gained in the vicinity of a pneumatic driller.

Records in tunnel with a longer time and a lower sampling rate, contrast with that on the surface. Moving-coil geophones are used, dominant frequency is 100Hz. DZS-1 digital deep seismograph produced by Chongqing Geological Instrument Factory achieves a long records. The data recorded a total of 3h, the sampling rate of 1000Hz. A total of 9 geophones, group interval is 30m, on the ground parallel to the direction of the shearer working face. The shearer is in the tunnel underground about 120m.

3. Near-field signal characteristics of Shearer

Shearer is available to be a source or not? Important indicators is seismic signal must have comparatively wide spectrum and strong enough. Near-field record is aimed to address the first issue, which is to analysis the signal spectrum; Far-field record studies the second issue, which is in the usual practical scale, the adequacy of the energy source.

Fig.2 shows the three-component vibration signals recorded in the shearerat the corner of working face and air return way. h1 and h2 is horizontal ones, h1 is parallel to working face, and h2 is perpendicular to h1, z is vertical component. In waveform, the three components are differentiated with each other obviously: h1 looks like noise; h2 has strong mono-frequency component; z is between h1 and h2. Amplitude spectral analysis (in Fig.3) shows h1 is a wide band signal, and is strongest below 600 Hz; the most important feature of h2 is a narrow band component of 64 Hz; z also has other relatively wide band components. In spectrums of h1 and z, there are some narrow band peaks, and it shows that periodic noise sources are much more in tunnel, the record is complex.

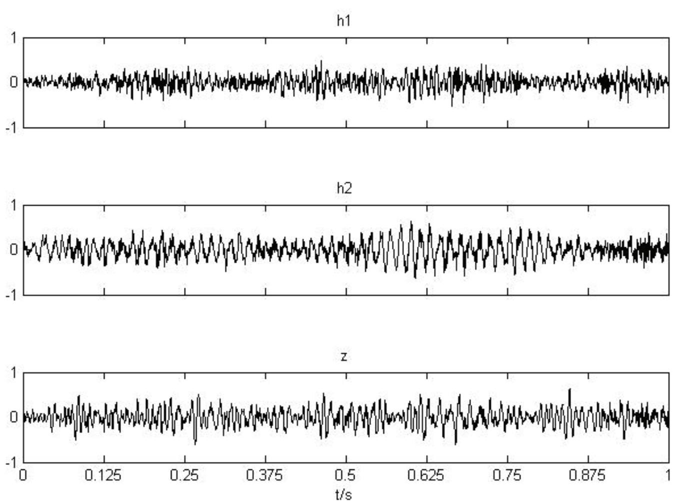

Fig.2 .Near-field record shea

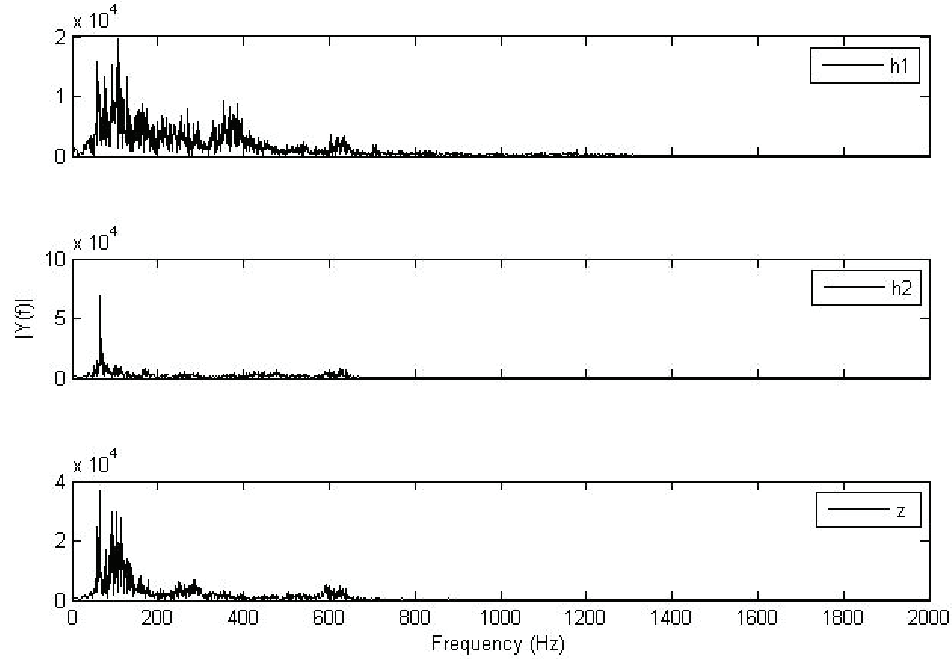

Fig.3. Amplitude spectrum of near-field record of shearer

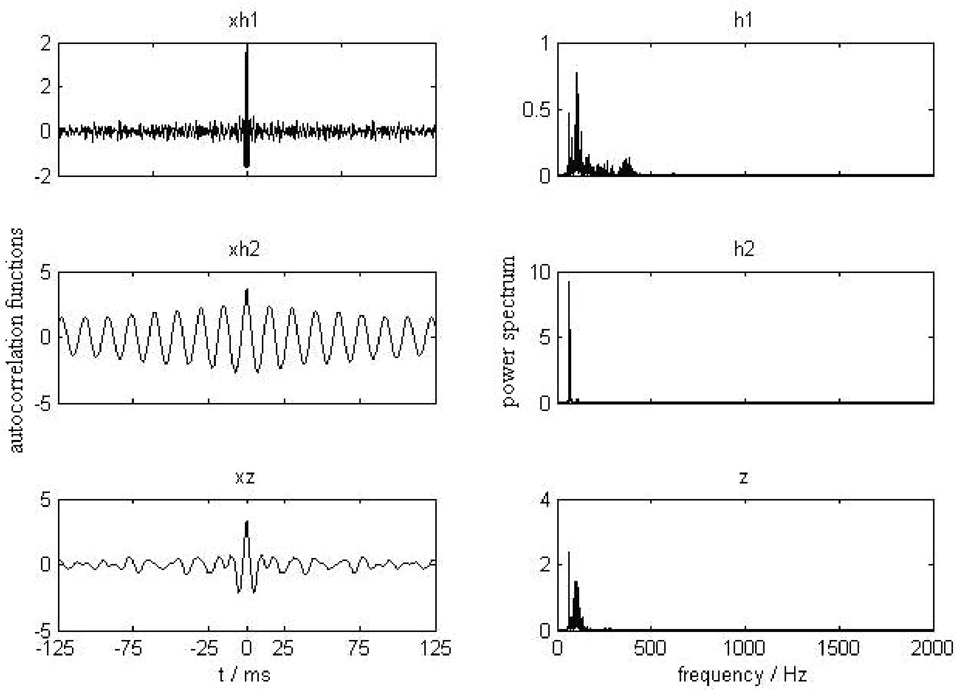

Fig.4. Autocorrelation and power spectrum of near-field record of shearer

Fig.4 shows the autocorrelation and power spectrum. The autocorrelation of h1 is a sharp peak, it means that the spectrum is wide; the autocorrelation of h2 is a mono-frequency component; the power spectrum of z is relatively narrow and side lobe is large.

The above analysis shows that the shearer near-field signal is complicated, it has both the component similar to broadband white noise and strong cyclical component, and has obvious direction characteristic.

4. Far-field ground signal characteristics of shearer

Coal tunnel is about 120m under the surface. The 9 geophones line at the surface is roughly parallel with the coal face, and the group interval is 30m.

Fig.5 is a part of the signal; envelope shows the working status of the shearer. Status of the shearer has a strong time-varying: from start to about 45s is stop mining time, 3s of the record in A interval in Fig.5 is analyzed; from about 45s to 70s is mining time, take C section to carry out the analysis; after 70s is mining time in greater intensity, take D section to carry out the analysis. Many microseismic events were recorded, but here is no obvious regularity in sizes and locations. Fig.5 shows one of the events.

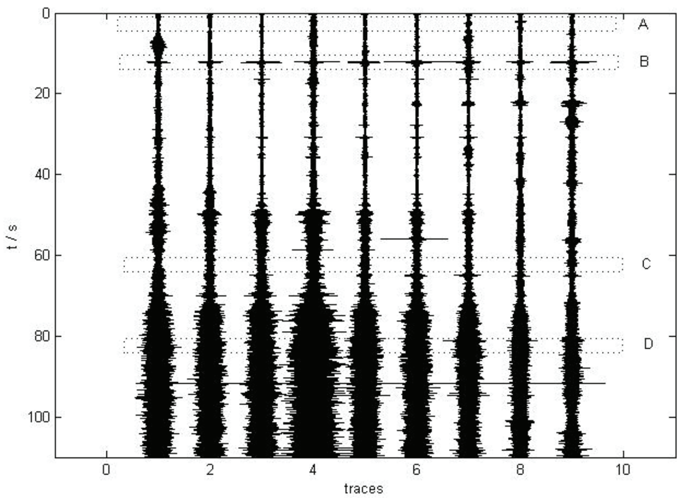

Fig.5. Signals of the shearer recorded at the surface

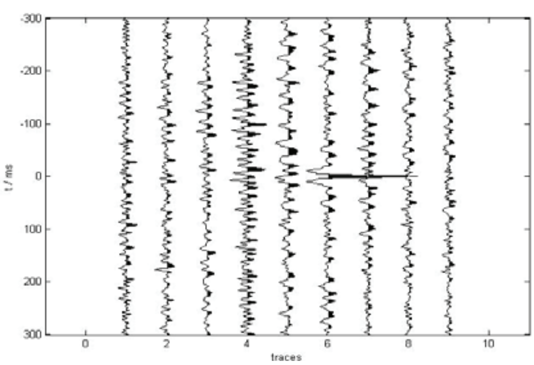

Fig.6. Correlogram of record A section in Fig.5 (No.6 trace is pilot)

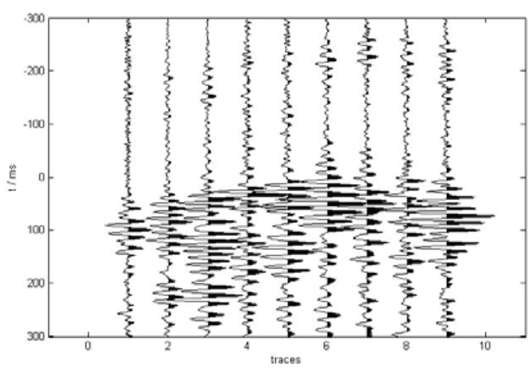

Fig.7. Microseismic event in B section in Fig.5

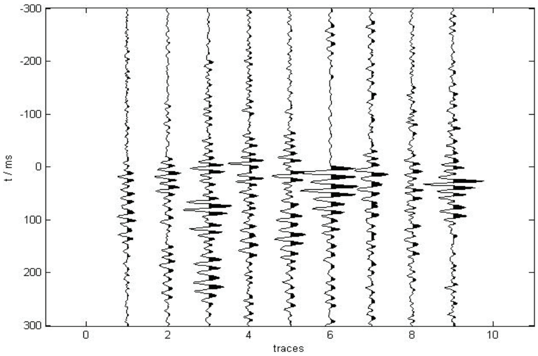

Fig.8. Correlogram of microseismic event
(No.6 trace is pilot)

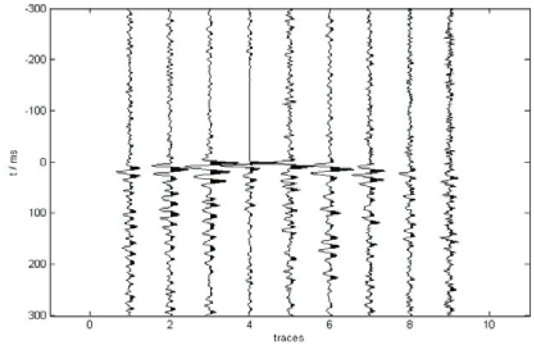

Fig. 9. Correlogram of C section in Fig.5
(No.4 trace is pilot)

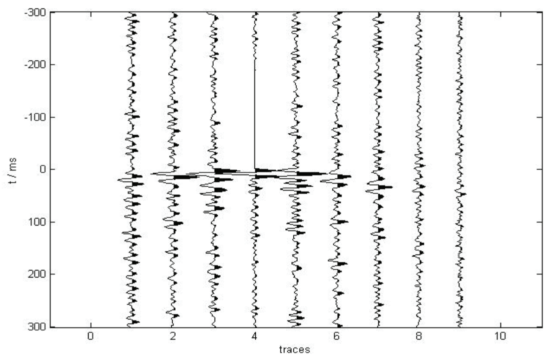

Fig.10. Correlogram of D section in Fig.5 (No.4 trace is pilot)

In Fig.5, the amplitude of signal in A is relatively small compared with the mining records. We take No.6 trace as pilot signal, make correlation functions with all of the channels, and are shown in Fig.6. There is noise except No.6 trace itself, which is a autocorrelation peak. This means when suspend mining, energy of the shearer vibration signal is weak.

A microseismic event in section B in Fig.5 is zoomed in Fig.7. By travel time, the source is near to No.6 or No.7 geophone. We take No.6 trace as pilot signal to make correlogram, as shown in Fig.8. The event in Fig.8 seems to be no good as that in Fig.7, and it means that the microseismic event couldn't be source directly.

Fig.9 and Fig.10 show cross-correlation results of C and D section data in Fig.5 respectively, taking No.4 trace as pilot, and both figures show clearer direct wave. Event in Fig.9 is relatively better than that in Fig.10.

Fig.11 is the spectral analysis of A, B, C, D four-stage in Fig.5, for No.4 trace, it is found that every of the four stages is wide band. A strong component of 16.6Hz is in A section. There are two strong narrow band components in B section. The spectrum of C section is slightly wider than that of D section, in particular in low-frequency.

Superimposed spectral analysis of nine traces of four-stages of A, B, and C, D is shown in Fig.12. Comparatively analyzed with Fig.11, it is found that 16.6Hz component has been considerably rengthened in Fig.12 (a), indicating that there is a periodic source, but less energy; the band of traces in Fig.12 (b) was narrower than those in Fig.11 (b), it means that the microseismic event is narrow-band;

Compared to the near-field record, the far-field spectrum has less high frequency components, but still is broadband compared with the average sources.

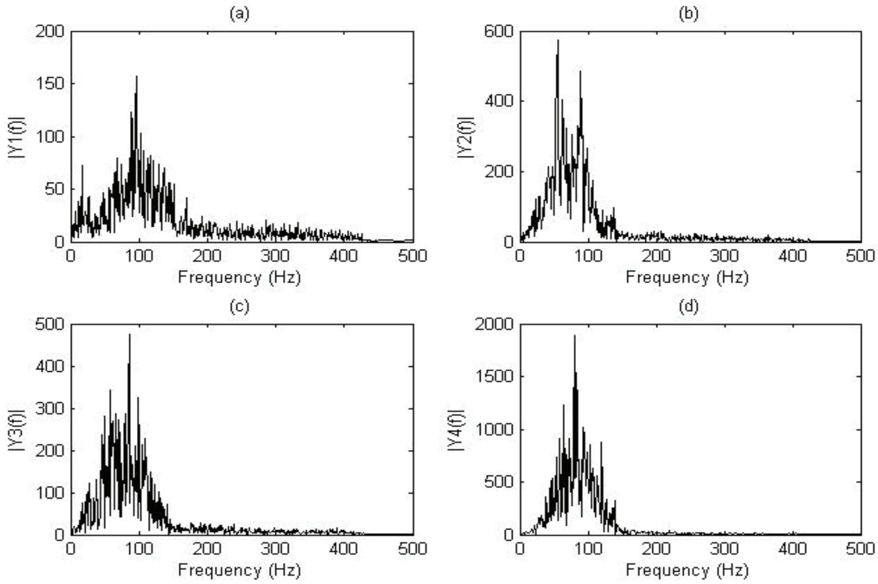

Fig.11. Amplitude spectrums of four sections in No.4 trace in Fig.5. (a) stop mining，(b) microseismic，(c) mining (low intensity)，(d) mining (high intensity)

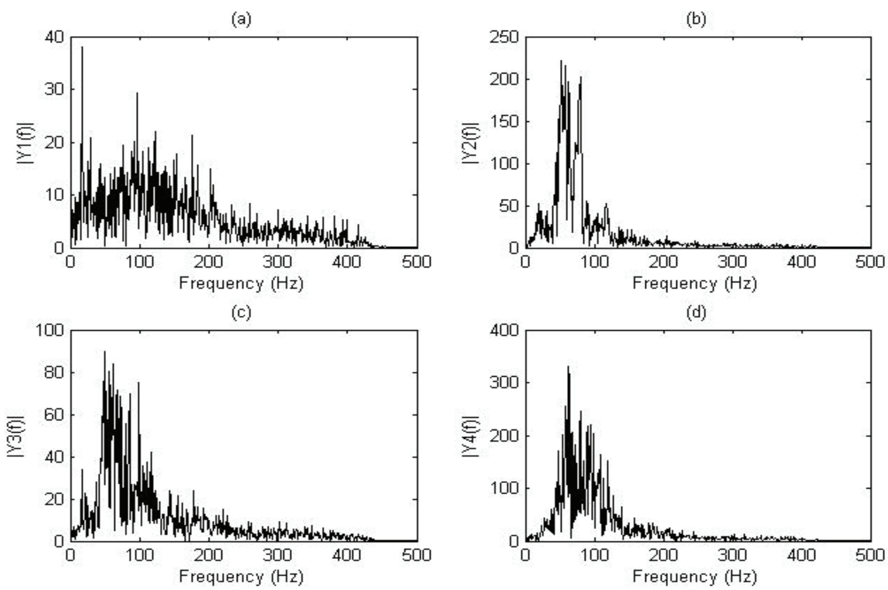

Fig.12 Superposition of amplitude spectrums of four sections of nine traces in Fig.5. (a) stop mining，(b) micro-seismic，(c) mining (low intensity)，(d) mining (high intensity)

5. signal features of boring machine and pneumatic drill

Boring machine and pneumatic drill are two kinds of devices that are commonly used in coal mine. Ahead prediction for the boring machine is also very important. We study these two types of mechanical vibration recorded in near-field.

5.1. Signal features of boring machine

Near-field signal is recorded in the tunnel about 8m apart from the boring machine, as shown in Fig.13. h1 and h2 is the horizontal component, h1 is parallel to the roadway, h2 is perpendicular to h1, z is the vertical component. Fig.14 shows amplitude spectrums of a horizontal component h1 and vertical component z, and the horizontal component has strong low-frequency components, vertical component is more balanced in the spectrum, both 'h1' and 'z' have a stronger narrow peak. Fig.15 shows the auto-correlation functions and power spectrums. z component has sharper wavelet, and larger side lobes in the autocorrelation functions of horizontal components. Power spectrum shows strong narrow-band periodic component. Overall, the boring machine is also suitable as a seismic source, and the vertical component is better.

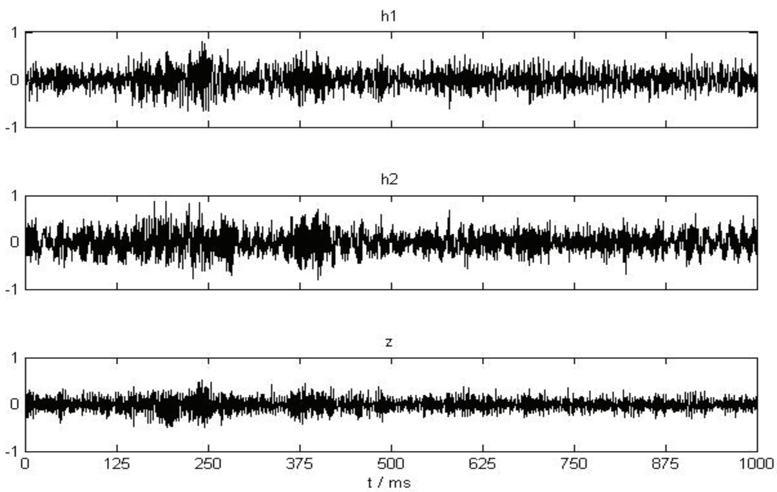

Fig.13. Near field signal of boring machine

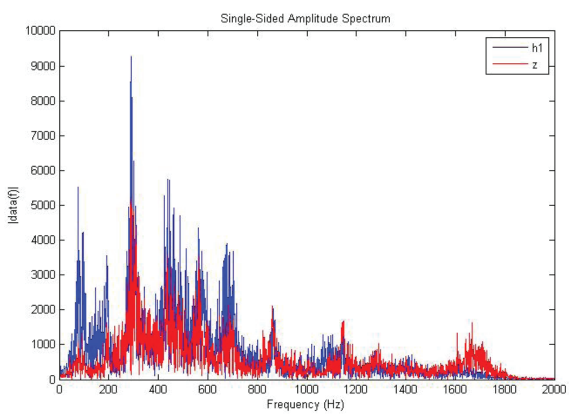

Fig.14. Amplitude spectrum of boring machine signals

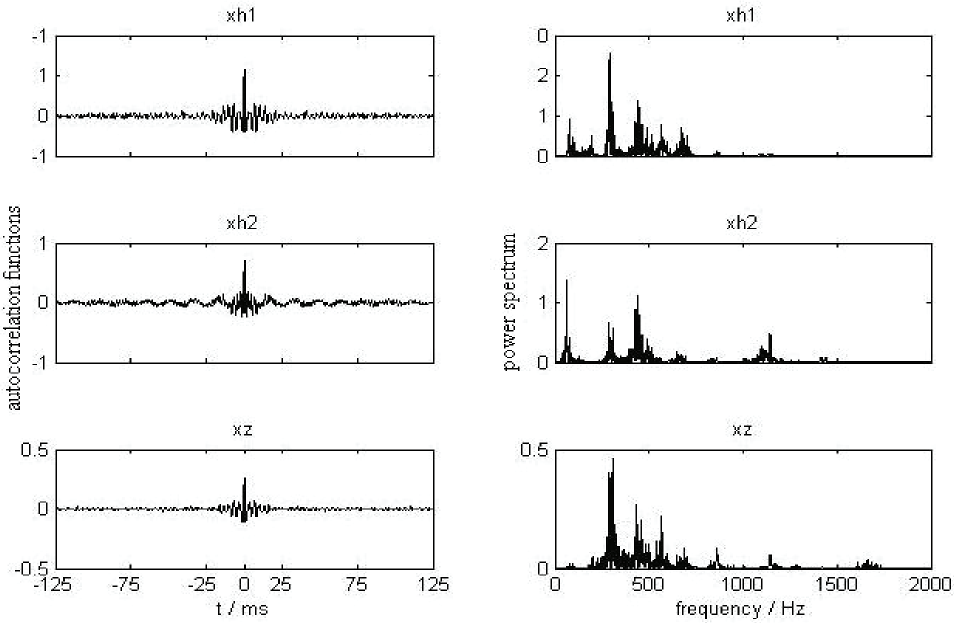

Fig.15. Autocorrelation functions and power spectra of boring machine signals

5.2. Signal features of pneumatic drill

Unlike the boring machine, the pneumatic drills work in a series of strong pulses (Fig.16a), the cycle characteristics is significant, and the autocorrelation function does not show periodicity (Fig.16b). Contrast the entire record of the spectrum (Fig.16c) and the single pulse spectrum (Fig.16d), it is found that they are basically the same, proving once again that a pneumatic drill band is very wide, and suitable for use as a source.

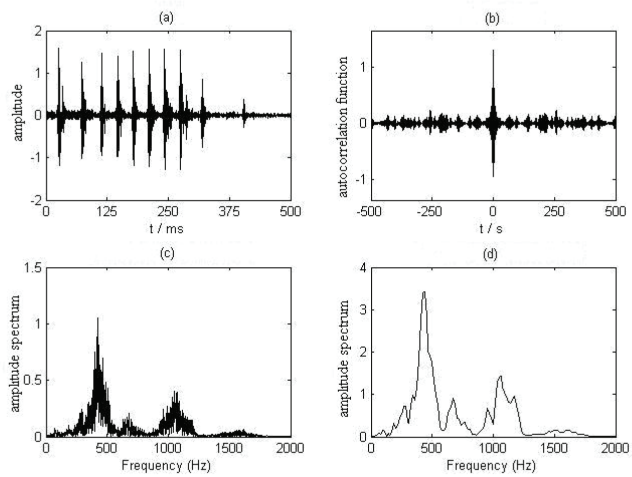

Fig.16. Pneumatic drill signal and its features

6. Discussion

Near-field test is more difficult, partly because of the narrow tunnel, and it is dangerous to test near the work face, and can not be free to experiment; on the other hand, in tunnel the instruments must be explosive proof. Intrinsically safe instruments can record relatively short record, so we still have to continue such testing and study to continuously improve knowledge.

Far-field signals are recorded on the ground, but lack of far-field signals in tunnel. In future study, we will add this test. The best test is an incorporate one with near-field, far-field both in tunnel and at the surface, can draw more meaningful conclusions. This study preliminarily shows that the mine shearer, boring machine, pneumatic drills are suitable for carrying out the passive seismic source with the mining.

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